University of Applied Sciences and Arts Northwestern Switzerland
School of Life Sciences

POSEIDON a Decision Support Tool for Wastewater Reuse

EIA Spring 2022 Irrigation Forum: Water Reuse in Irrigation

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Institute for Ecopreneurship (IEC)

- Part of the School of Life Sciences of the University of Applied Sciences and Arts Northwestern Switzerland (FHNW),
- Located in the heart of the tri-national area of Basel (Switzerland, France and Germany).
- IEC covers the entire life cycle of technologies from proof of concept and valorisation to implementation, monitoring and evaluation.
- Multiple laboratories equipped with state-of-the-art analytic instruments
- Process Technology Centre with a complete modular pilot wastewater treatment plant covering all modern treatment stages.
- Water reference frameworks, conclusive indicator systems and decision support systems like POSEIDON

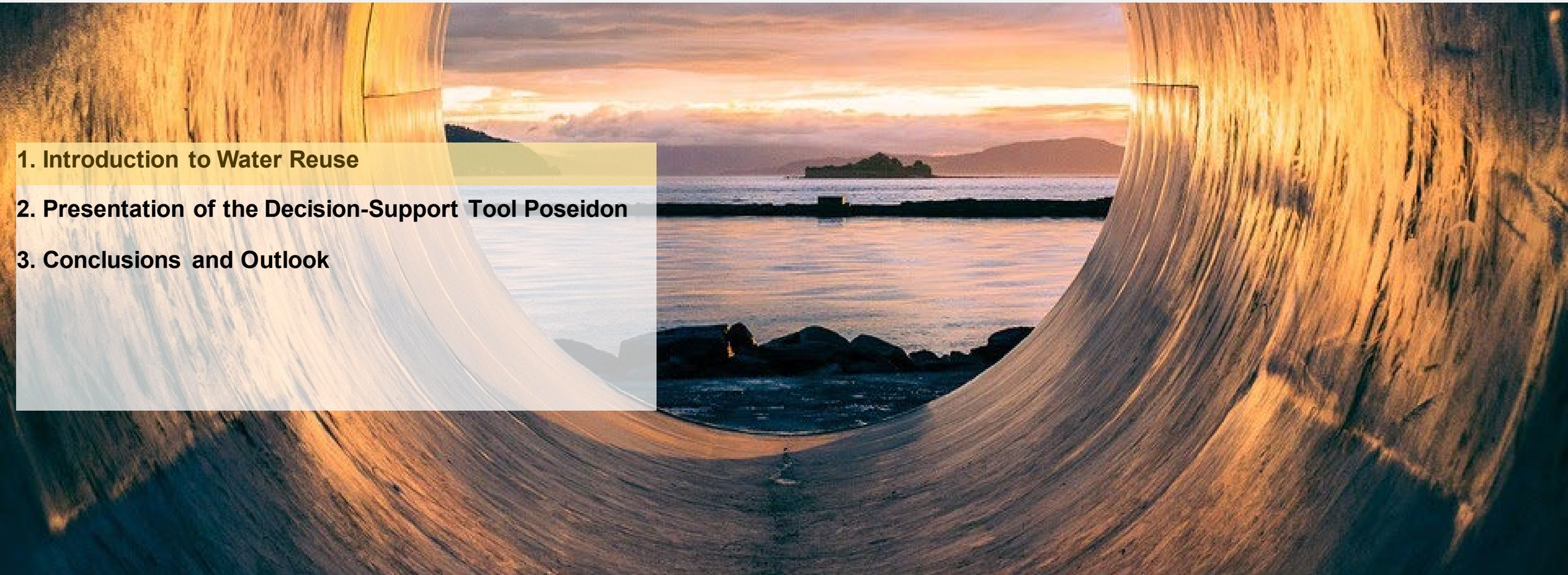
Schedule

1. **Introduction to Water Reuse**
2. **Presentation of the Decision-support Tool Poseidon**
3. **Conclusions and Outlook**

Learning Objectives

Learn about the decision-support tool POSEIDON for water reuse and how to consider a holistic approach for pre-feasibility studies.

1- Introduction to Water Reuse



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The Growing Water Crisis

- One-quarter of the world's population (**17 countries**), face "**extremely high**" levels of **water stress**.
- By 2030, the world is projected to face a **40% global water deficit** between **global water requirements** and the **current accessible and reliable supply**.

WORLD RESOURCES INSTITUTE

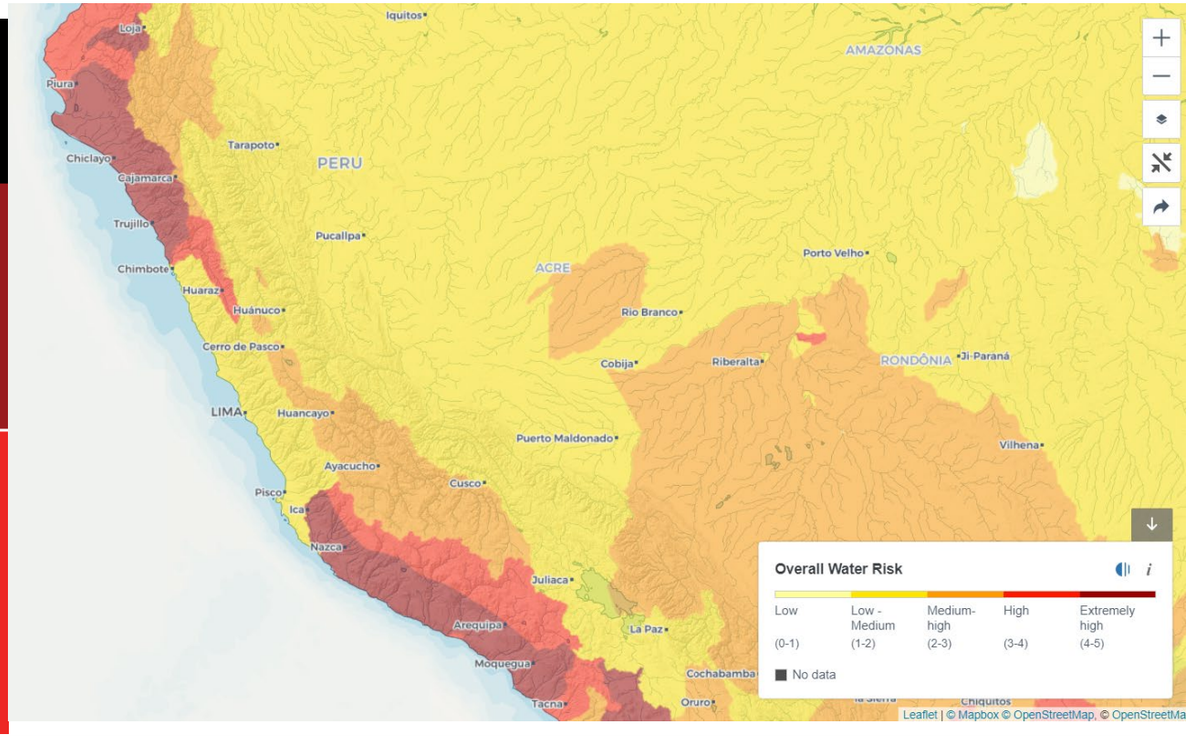
National Water Stress Rankings

EXTREMELY HIGH BASELINE WATER STRESS

1. Qatar	6. Libya	10. United Arab Emirates	14. Pakistan
2. Israel	7. Kuwait	11. San Marino	15. Turkmenistan
3. Lebanon	8. Saudi Arabia	12. Bahrain	16. Oman
4. Iran	9. Eritrea	13. India	17. Botswana
5. Jordan			

HIGH BASELINE WATER STRESS

18. Chile	25. Uzbekistan	32. Turkey	39. Niger
19. Cyprus	26. Greece	33. Albania	40. Nepal
20. Yemen	27. Afghanistan	34. Armenia	41. Portugal
21. Andorra	28. Spain	35. Burkina Faso	42. Iraq
22. Morocco	29. Algeria	36. Djibouti	43. Egypt
23. Belgium	30. Tunisia	37. Namibia	44. Italy
24. Mexico	31. Syria	38. Kyrgyzstan	



Source: World Resources Institute, 2019

What is Water Reuse

Definition

Water or wastewater reuse, recycling or also called reclamation is the process of **treating wastewater into water of a quality that can be reused for beneficial purposes**.

→ *Treatment technologies are available to achieve any desired level of water quality*

Source: US EPA Water Reuse Guidelines, 2012

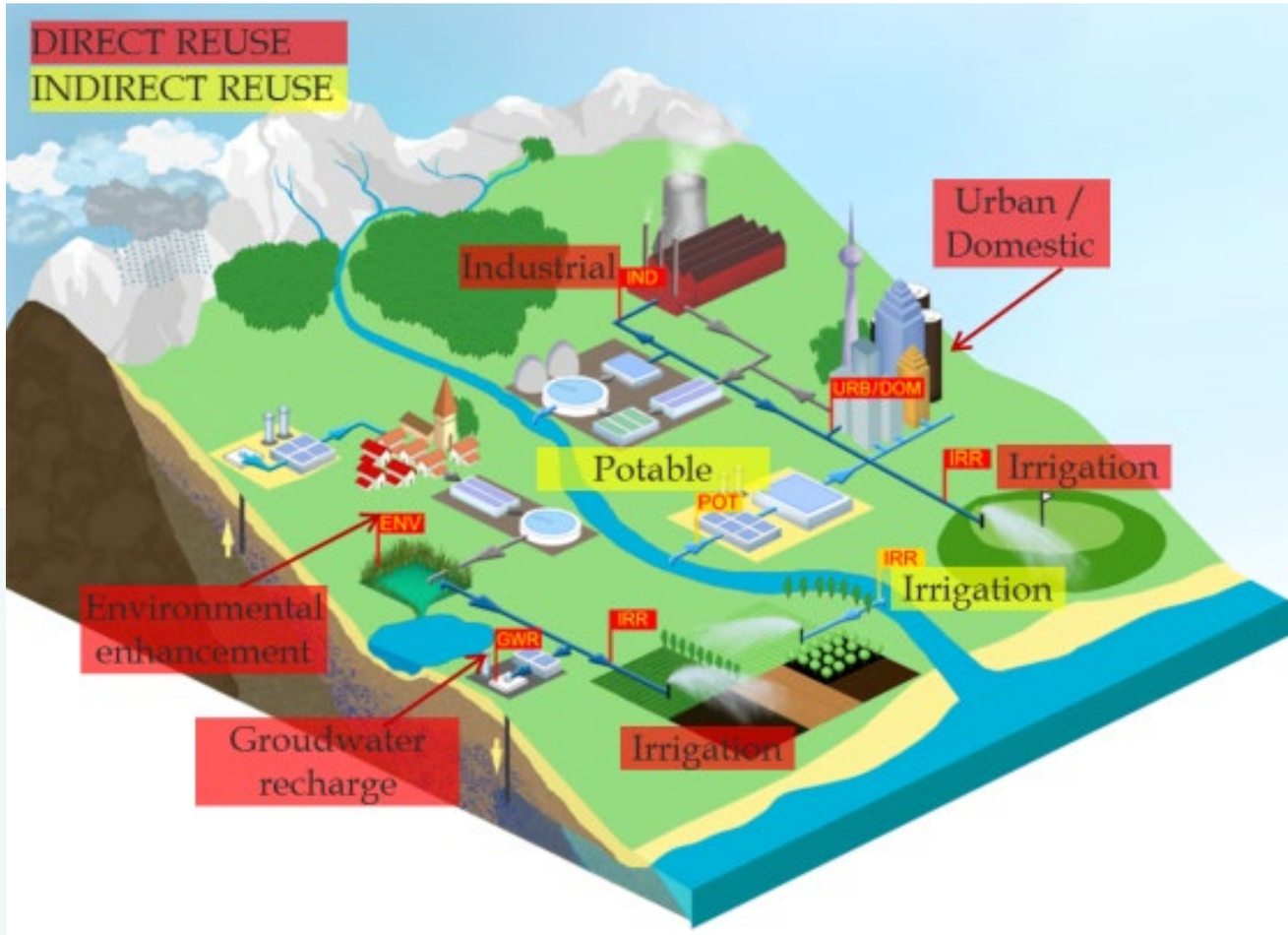
Water Reuse - The anthropogenic water cycle with direct and indirect reuse

The objective of wastewater reuse is the treatment of wastewater to a quality that can directly be used for specific purposes. We differentiate:

- **Direct reuse**
- **Intentional indirect reuse**
- **Unintentional indirect reuse**

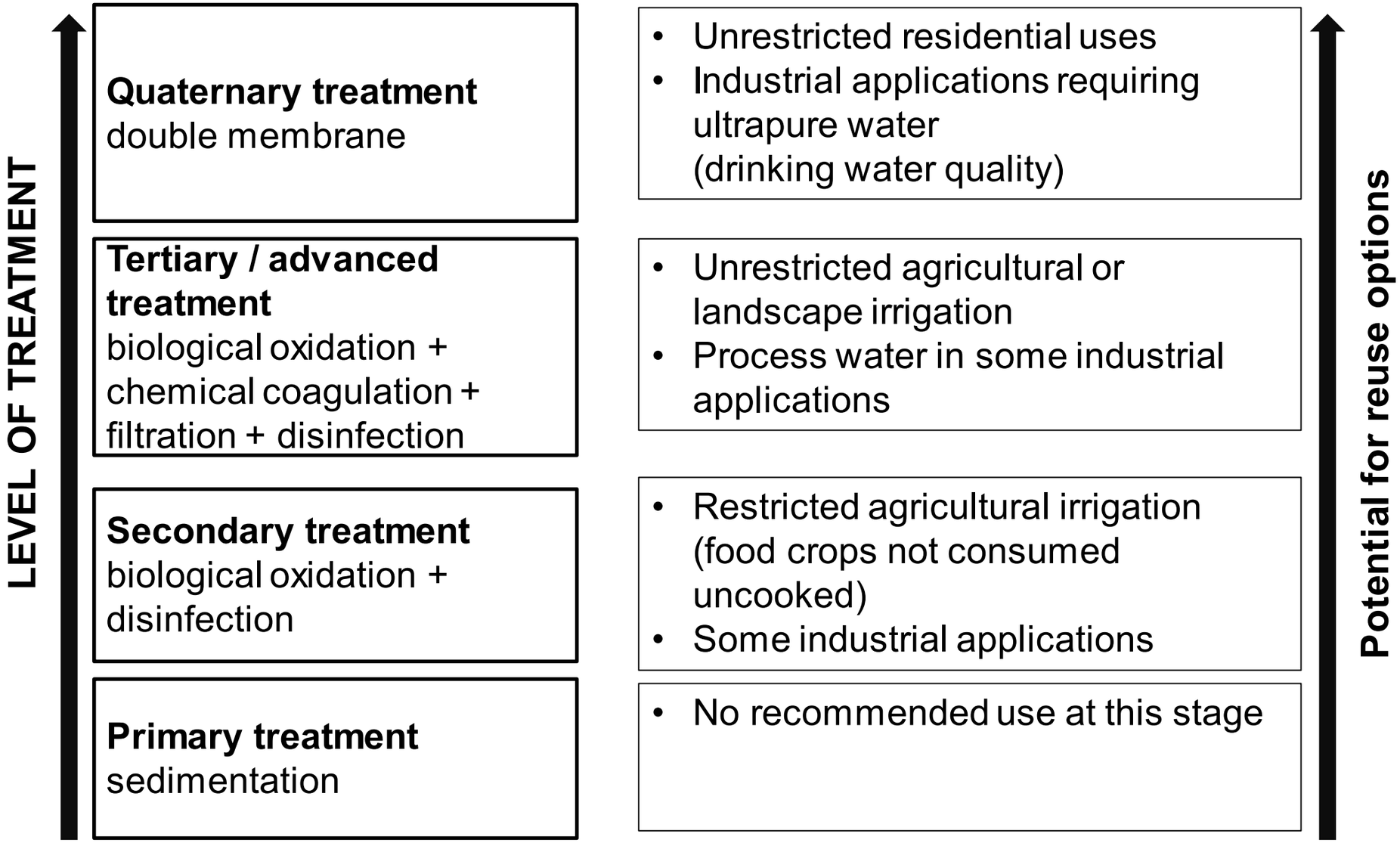
Two main incentives:

- Treated wastewater can be reused as a water resource for beneficial purposes, **substitutes abstraction of other (ground-)water resources**
- Wastewater is kept out of receiving environments thus **reducing polluted discharge** into receiving bodies



Source: (Wintgens and Hochstrat 2006)

Different levels of treatments and potential options for reuse



Source: TREATED WASTEWATER REUSE IN THE MEDITERRANEAN: LESSONS LEARNED AND TOOLS FOR PROJECT DEVELOPMENT

Authorized use of treated wastewater reuse by country (non-exhaustive)

	Cyprus	Egypt	France	Greece	Israel	Italy	Jordan	Lebanon	Morocco	Portugal	Spain	Syria	Tunisia	West Bank	(Saudi Arabia)	(Koweit)	(Oman)
Agricultural Irrigation		C+F+E										C+P	C	C	C	C	
Ladscape Irrigation/ golf courses		**															
Aquifer Recharge												*					
Environment																	
Industrial Recycling																	
Urban Use																	
Domestic Use																	
Potable Water																	
	(1)		(1)			(1)		(2)		(1)	(1)			(1)	(2)	(2)	(2)

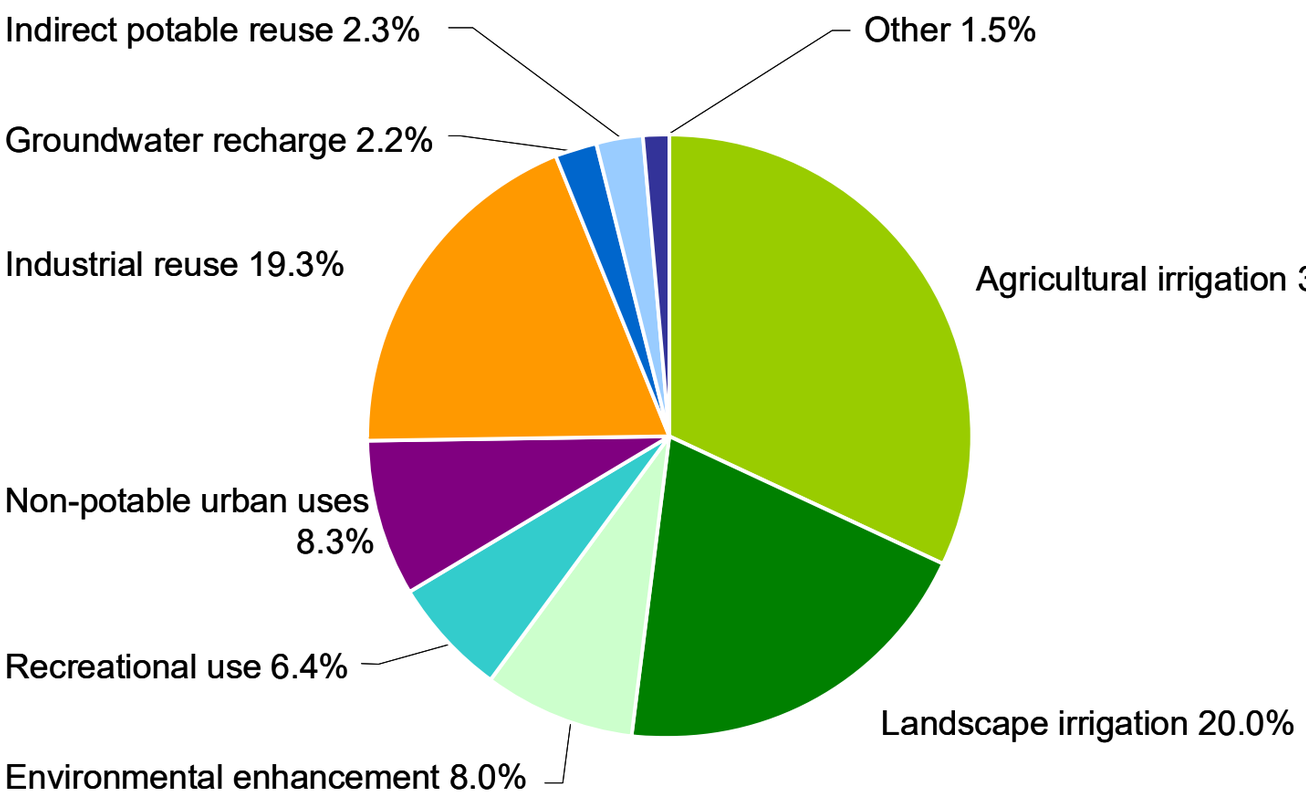
C: Products eaten raw - F: Fruit withour pericarp - E: Crops for export - P: Pasture
* Aquifers exploited for drinking water
** Excluding green areas in schools

Source: Compiled by the author - Data sources: (1): Eureau - (2): Xanthoulis (2010)

Regulated / Banned
Regulated / Authorized
No regulations

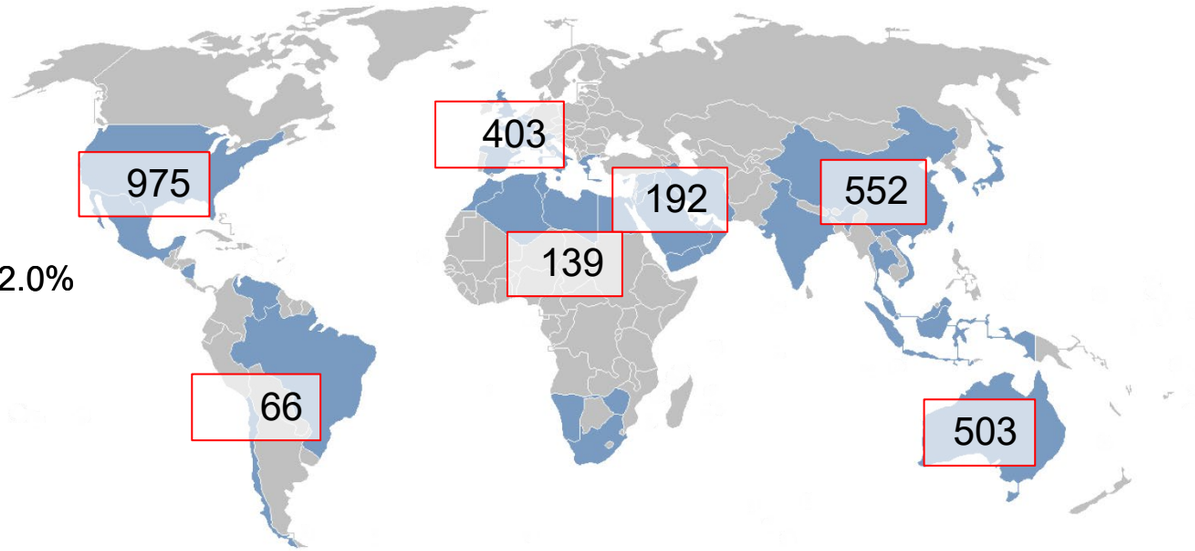
Source: TREATED WASTEWATER REUSE IN THE MEDITERRANEAN: LESSONS LEARNED AND TOOLS FOR PROJECT DEVELOPMENT

Distribution of global water reuse applications with secondary or higher treatment levels



Source: Kazner, 2012, GWI/PUB Water Reuse Inventory, 2009

Water reuse projects – number of schemes (2009)



GWI GLOBAL WATER INTELLIGENCE

Source: Data of GWI – Reuse markets (2009)

Source: Hochstrat, 2018

https://www.globalwaterintel.com/global-water-intelligence-magazine/project-trackers

Desalination Benchmark

- **Multi-Stage-Flash (MSF)**: thermal, 90 – 120 °C
- **Multiple-Effect Distillation (MED):** thermal, < 70 °C
- **Reverse Osmosis (RO):** mechanical, membranes, energy recovery

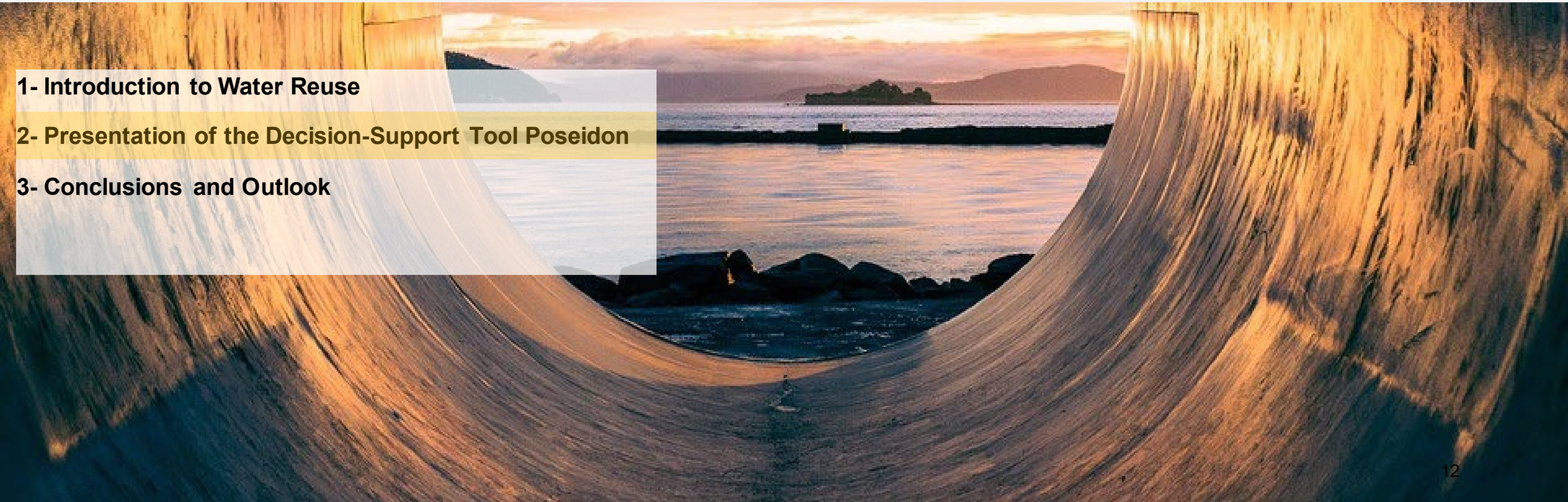
Tuas Desalination Plant can produce up to 110'000 m³ a day of drinking water, the amount used by around 200,000 households daily. With it, 30 per cent of Singapore's water needs can now be met by desalination, up from 25 per cent.

Process	Unit	Specific desalinated water costs		
		low	average	high
MSF	$/m³	1.00	1.79	2.66
MED	$/m³	1.24	2.09	2.93
RO	$/m³	0.69	0.79	0.89

		based on the following specific energy prices		
		low	***average***	***high***
thermal	*$Ct/kWh*	*1.25*	*2.50*	*3.75*
electrical	*$Ct/kWh*	*3.00*	*6.00*	*9.00*

Source: Laupichler, 2012

2- Presentation of the Decision-Support Tool Poseidon



1- Introduction to Water Reuse

2- Presentation of the Decision-Support Tool Poseidon

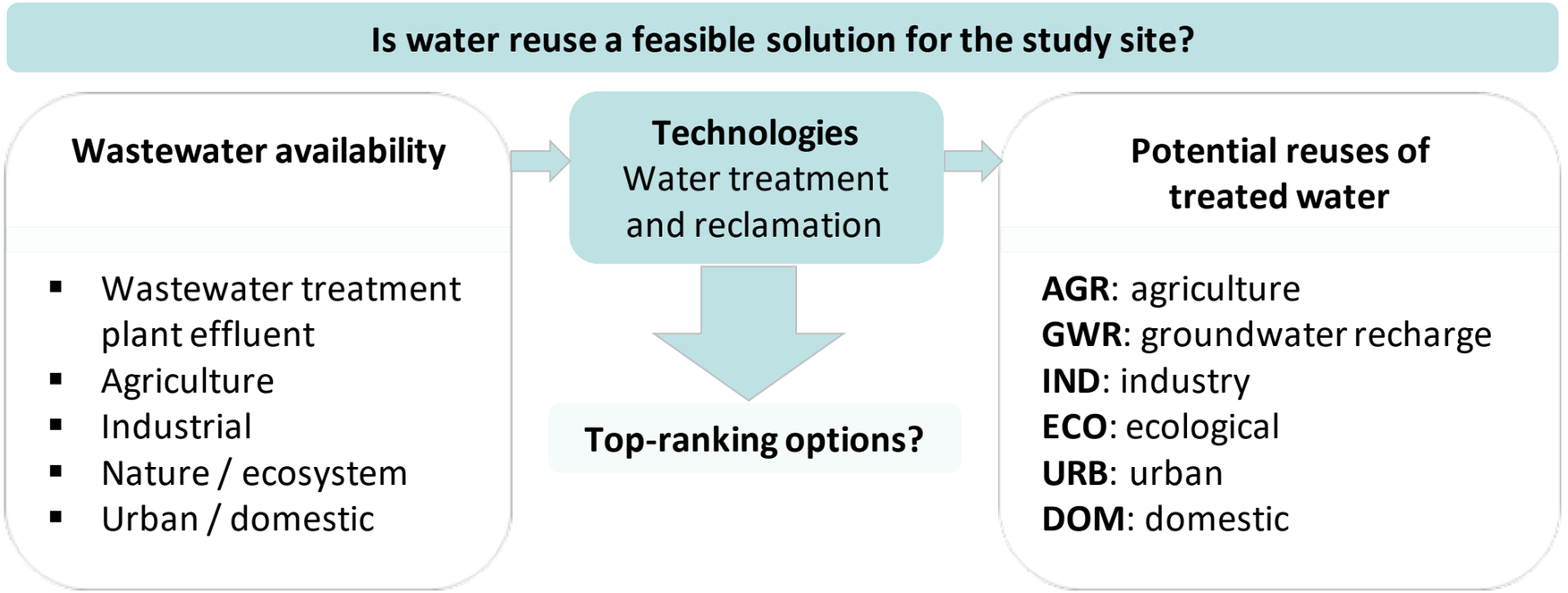
3- Conclusions and Outlook

Objectives and Elements of Poseidon

- Poseidon is a **free decision support tool** that supports **pre-feasibility studies** and aims at promoting water reuse and building capacities in this field.
- The tool currently encompasses **37 unit treatment processes** combined into **70 benchmark treatment trains**.
- It also contains information on **water quality standards** and **typical wastewater qualities**.
- It estimates the removal performances for **12 pollution parameters** and the lifecycle **costs** including distribution.

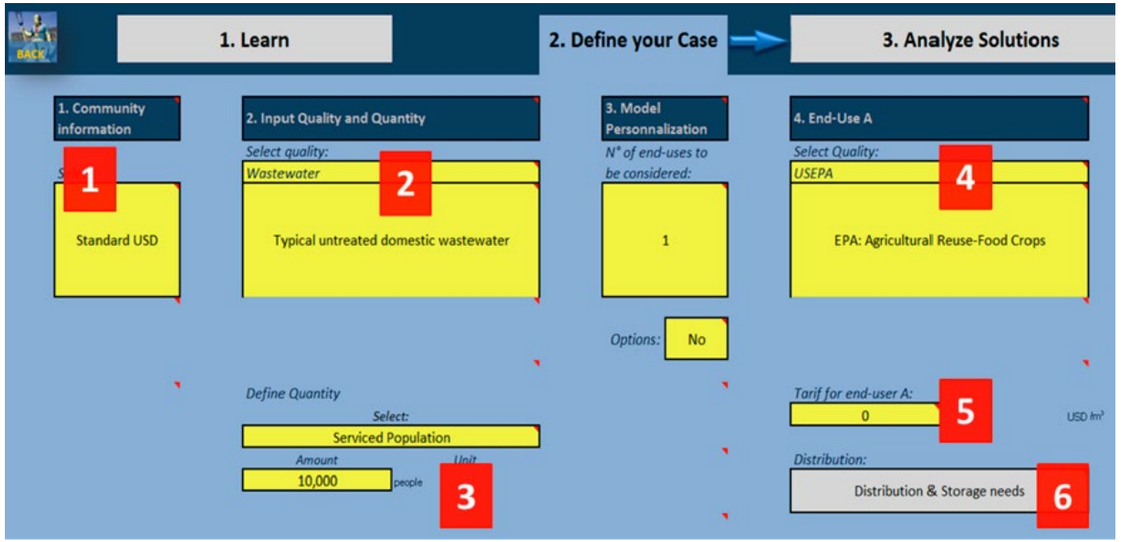
Excel Tool & Article are Open Access:
Article:
https://www.mdpi.com/2073-4441/11/1/153
Excel-Tool Poseidon:
https://zenodo.org/record/3341573#.X_cosBYo9PY

Methodology – Poseidon (Water Reuse)

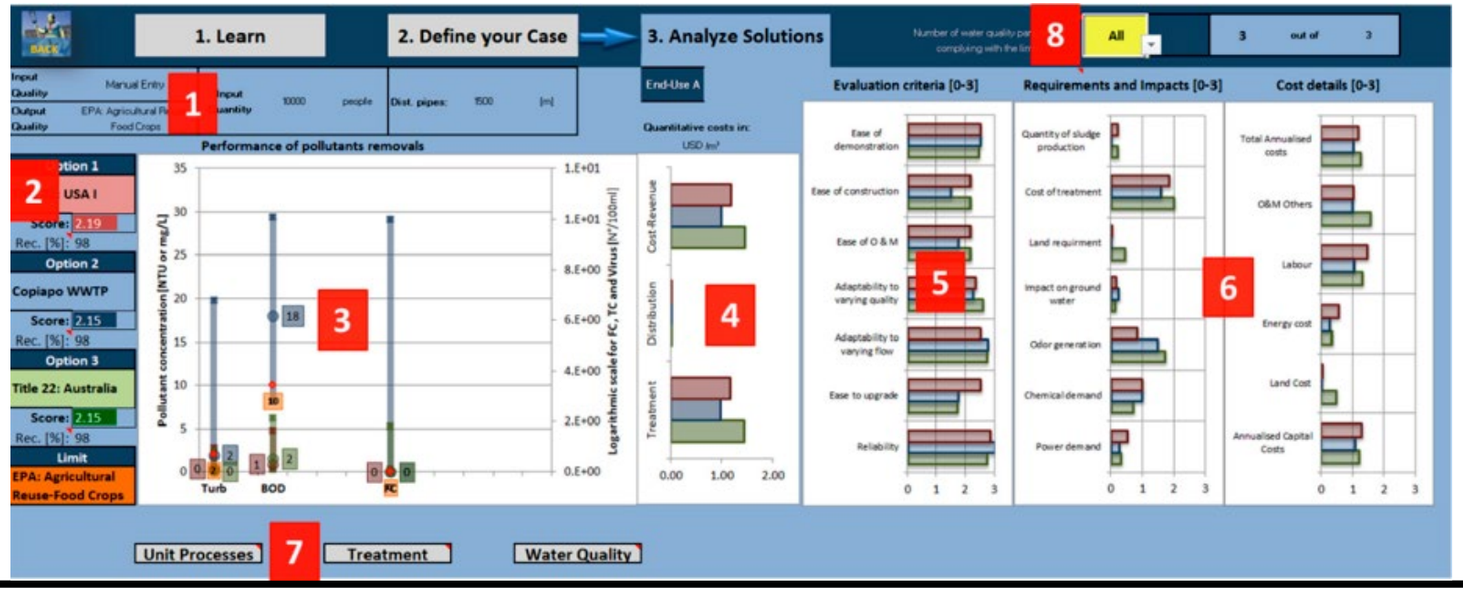


User Interface

Starting point:



Results:



Unit Treatment Processes (UTP): 37 UTPs included in Poseidon, more can be added by the users

Primary treatment	Disinfection
Bar screen	Chlorine gas
Coarse screen	Chlorine dioxide
Equalization basin	Ozonation
Grit chamber	Ultraviolet disinfection
Sedimentation without coagulant	
Sedimentation with coagulant	

Secondary Treatment	Tertiary Treatment
Anaerobic stabilization ponds	Constructed wetland
Activated sludge (high loaded with secondary sedimentation)	Activated carbon
Activated sludge (low loaded with denitrification and with secondary sedimentation)	Advanced oxidation process
Activated sludge (low loaded without denitrification but with secondary sedimentation)	Dual media filter
Extended aeration	Electrodialysis
Membrane bioreactor (MBR)	Enhanced biological phosphorus removal (EBPR)
Rotating biological contactor (RBC)	Flocculation
Stabilization ponds: aerobic	Ion exchange
Stabilization ponds: facultative	Maturation pond
Trickling filter with secondary sedimentation	Microfiltration
	Nanofiltration
	Post-Denitrification
	P-Precipitation
	Reverse osmosis
	Soil-aquifer treatment (SAT)
	Ultrafiltration

Treatment Trains consisting of UTPs: Almost 70 trains included, more can be added by the users

Category	Possible applications	Treatment trains included
1 - Title 22[1]	The reuse varies from urban applications, green landscaping to industrial usage.	Benchmark Technology, 11 case studies
2 - Soil aquifer treatment (SAT)	The final water can be reused for unrestricted irrigation.	Benchmark Technology, Israel, USA
3 - Wetlands	Reuse can be done in nature conservation or agriculture.	Benchmark Technology, 7 case studies
4 - Lagooning	Reuse of the effluent by (very) restricted irrigation.	Benchmark Technology, 8 case studies
5 - Disinfection only	Treated water can be reused for irrigation under restricted conditions.	Benchmark technology, USA, Chile, Brazil
6 - Direct membrane filtration	Treated water can be reused for agricultural applications.	Benchmark Technology, USA, Australia
7 – Local membrane bioreactor (MBR)	Reuse of the water in the direct neighborhood (e.g. as toilet flush water).	Benchmark technology, USA, Brazil, China, Japan
8 - High wastewater quality	The treated water is of so high quality that many applications (industrial, households, etc.) are possible.	Benchmark Technology, 7 case studies

1 The name of this benchmark technology originates from the homonymous Californian regulation.

Water Quality Parameters and Water Quality Classes

- **Water quality parameters:** 12 key parameters were considered
- **Pollutant removal performances for all UTPs**.

Parameter	Unit	Parameter	Unit
Biological Oxygen Demand BOD	[mg/l]	Total Nitrogen, TN	[mg/l]
Chemical Oxygen Demand COD	[mg/l]	Total Organic Carbon, TOC	[mg/l]
Fecal Coliforms, FC	[CFU/100ml]	Total Phosphorous, TP	[mg/l]
Nitrate	[mg NO_3-N/l]	Total Suspended Solids TSS	[mg/l]
Total Coliforms, TC	[CFU/100ml]	Turbidity	[NTU]
Total Dissolved Solids, TDS	[mg/l]	Virus (nonspecific)	[PFU/100ml]

- **Water Quality Classes** (more than 200):
  - **typical wastewater quality** that is intended for reuse.
  - **recommended water quality** based on **international guidelines and regulations.**

Lifecycle Cost Estimation

Objective: estimate any cost component for any technology in any location in the world.

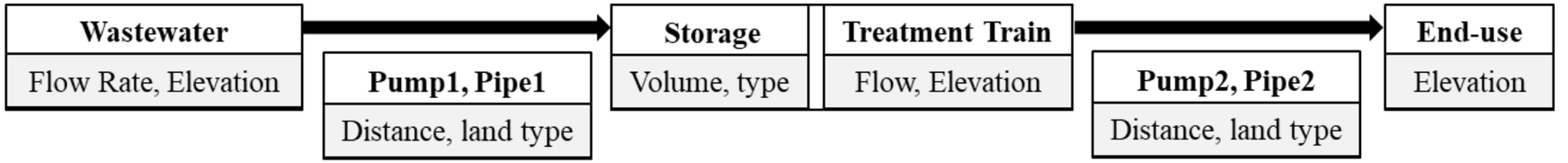
Community Information: local currency, exchange rate, land cost, electricity cost, personal cost, discount rate.

Cost Components: construction costs [*1'000 USD2006], land requirement [ha], energy required [kWh/y], labor requirement [person-hour/month], total annual operation and maintenance cost [*1'000 USD2006/y].

Database with cost coefficients: based on regressions, any cost component can be calculated with the flow rate and two coefficients.

Lifecycle cost algorithm: including indirect costs and annualized capital cost with capital recovery factor. All costs are calculated in [Local Currency/m^3 of reclaimed water].

Distribution and storage cost:



Multi-Criteria Assessment of Created Treatment Trains

Technical assessment criteria of the treatment trains [0-3]:
Reliability, ease to upgrade, adaptability to varying flow, adaptability to varying quality, ease of operation & maintenance, ease of construction, ease of demonstration.

Requirements and impacts [0-3]:
Power demand, chemical demand, odor generation, impact on ground water, land requirement, cost of treatment, quantity of sludge production.

Normalized costs component [0-3]:
Annualised capital costs, land cost, energy cost, labour, operation and maintenance - others, total annualised costs.

Overall treatment train assessment score (OA):

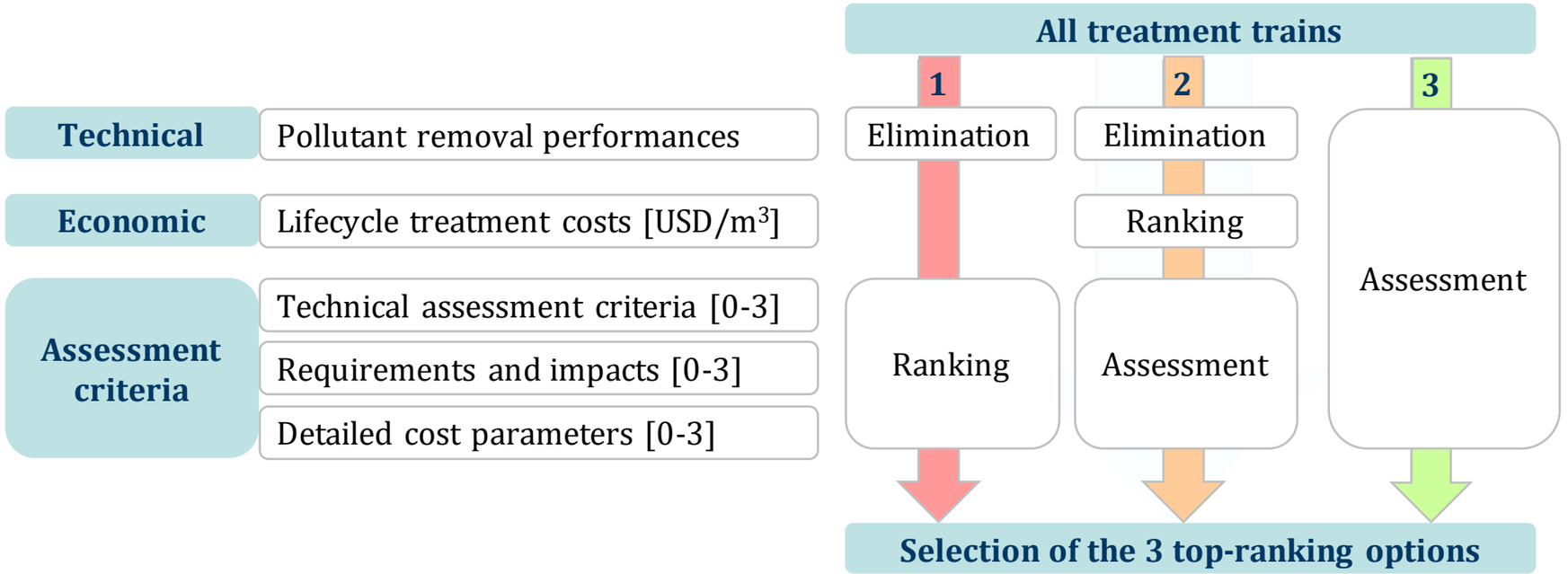
$$OA^{TT} = 3 \cdot \left(\frac{\sum_{i=1}^{M} W_i \cdot NC_i^{TT}}{\sum W_i} \right)$$

OA^{TT} = treatment train overall assessment score [-] (range 0–3),
W_i = weight of criteria i [-] (range 0–4, user-defined),
NC_i^{TT} = normalized criteria i score [-] (range 0–1), and
M = number of assessment criteria [-].

Note: for the criteria evaluated as negative (requirement and impacts, costs), the formula $1\text{-}NC_i^{TT}$ is applied in order to make every value in positive for the overall assessment score.

Assessment of Different Water Reuse Options

The DSS proposes three different assessment methods to **select three top-ranking options**:



Web based Poseidon Application

Project GIZ-PERU/ProAgua of the IEC

Development of an Online-Poseidon Tool to support decisions for treatment and reuse of municipal wastewater in Peru.

Requirements:

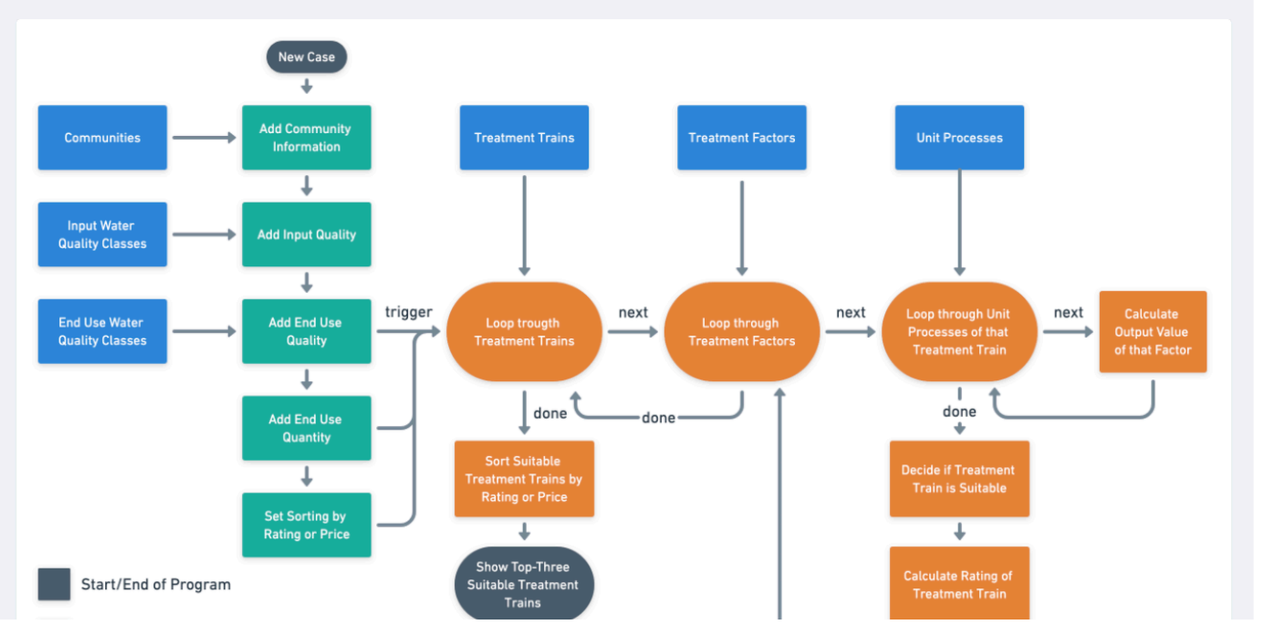
- Easy to use
- User friendly
- Multi-lingual
- Web based

Short Online Demonstration of Web based POSEIDON Tool

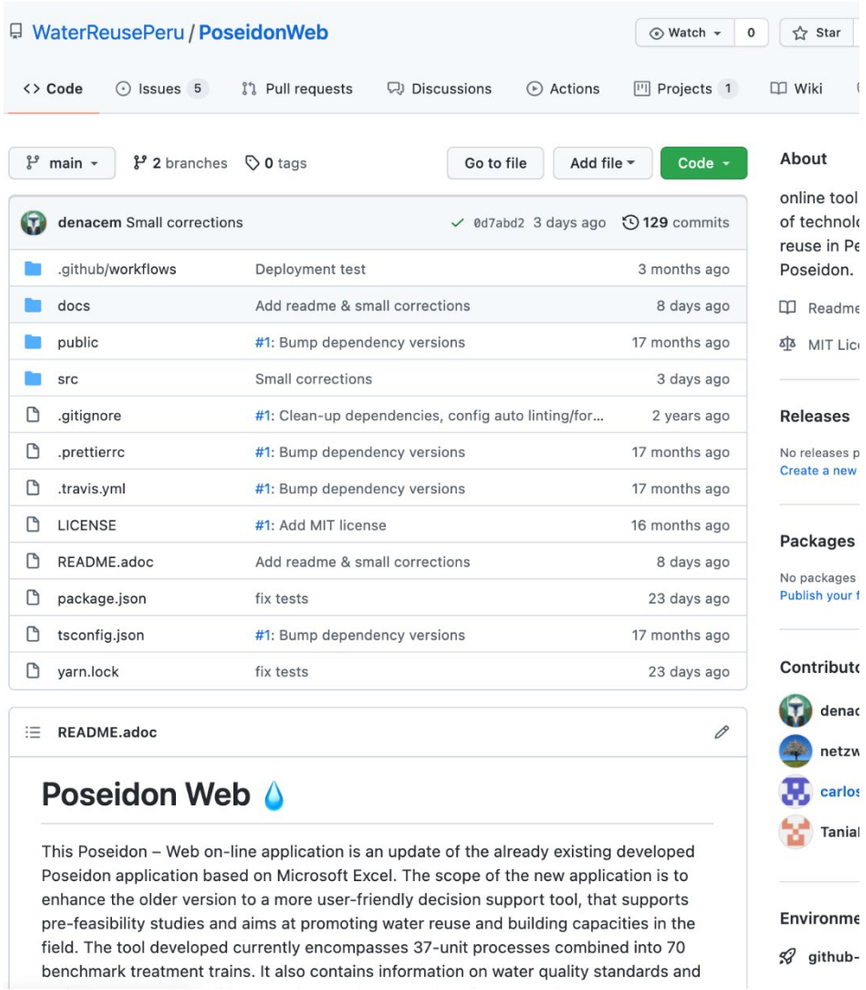
LEARN CASE RESULTS Poseidon Web beta ENGLISH

General Reference

This Poseidon – Web on-line application is an update of the already existing developed Poseidon application based on Microsoft Excel. The scope of the new application is to enhance the older version to a more user-friendly decision support tool, that supports pre-feasibility studies and aims at promoting water reuse and building capacities in the field. The tool developed currently encompasses 37-unit processes combined into 70 benchmark treatment trains. It also contains information on water quality standards and typical wastewater qualities. It estimates the removal performances for 12

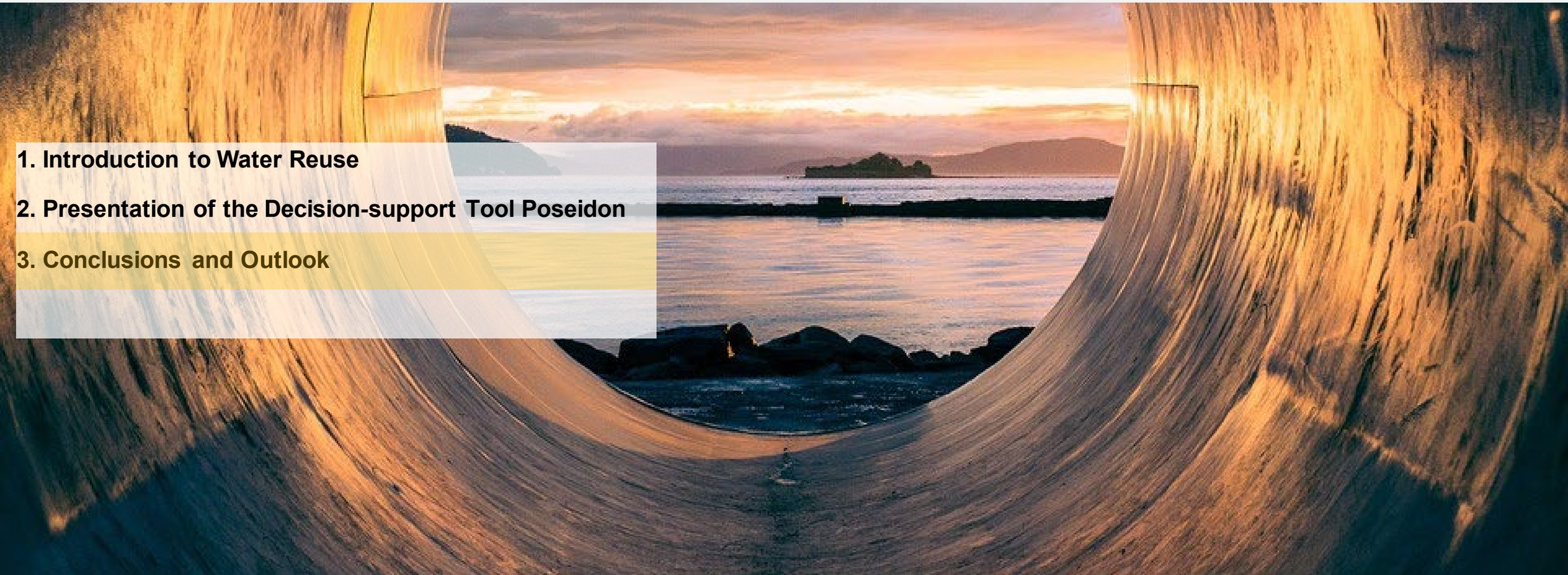


Future Developments



- Intentionally open source
- Currently implementing:
  - Ability to enter customized values
  - Create visualizations of detailed results
  - Possibility to add/remove quality factors
- Further ideas:
  - We're open for suggestions

3. Conclusions and Outlook



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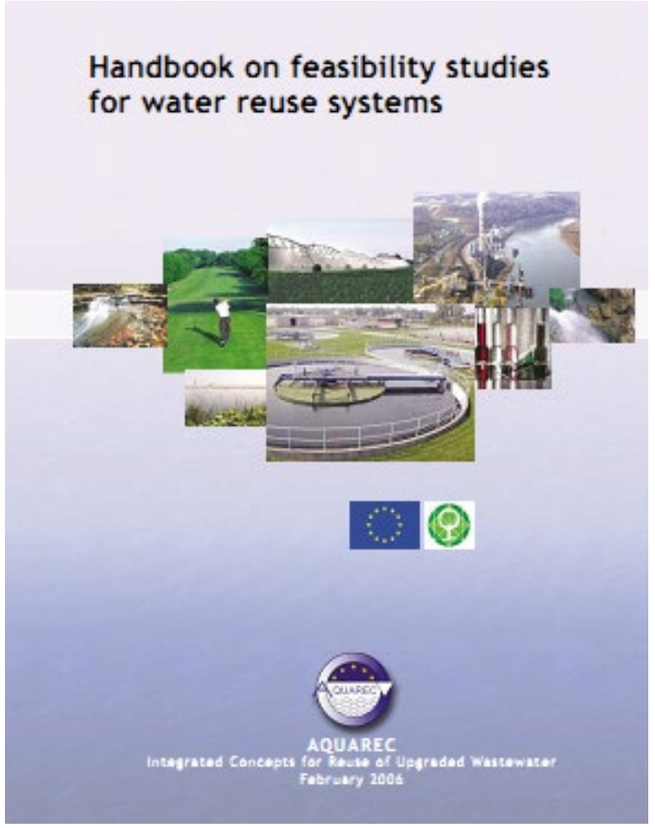
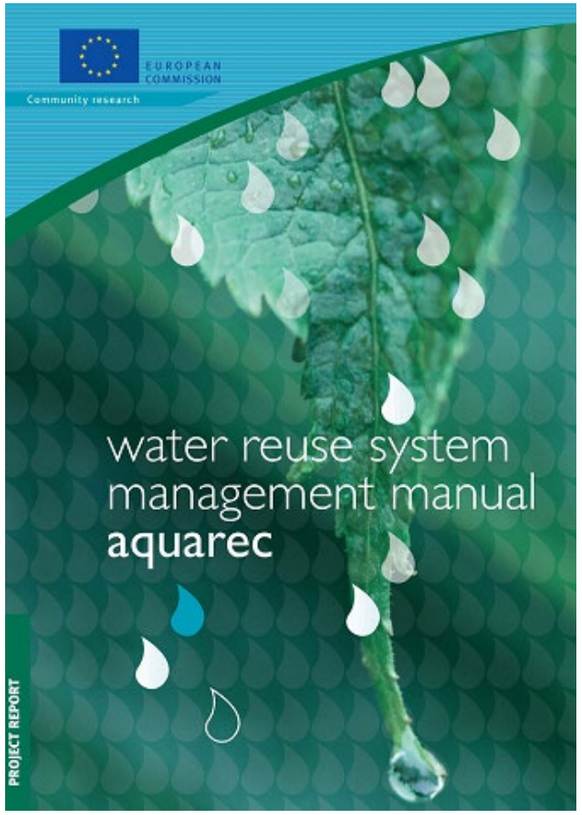
Conclusions and Outlook

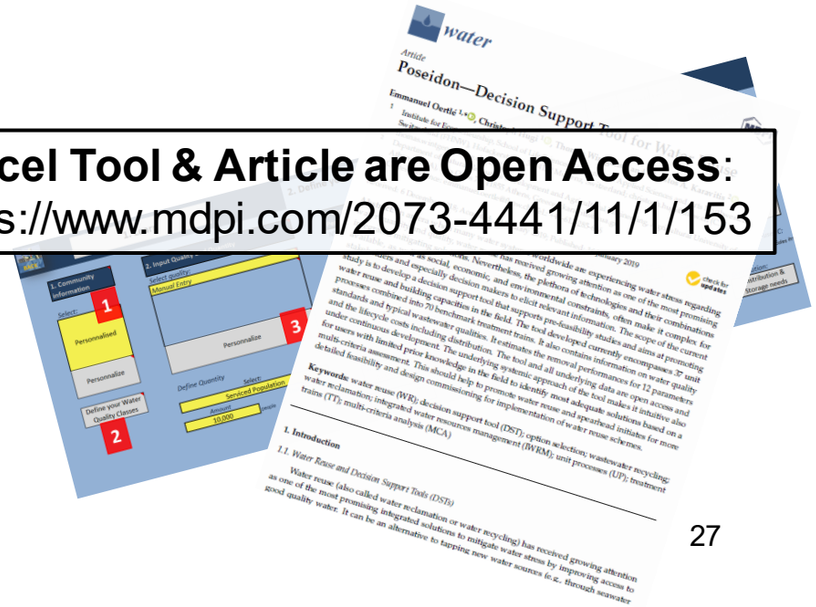
- Wide range of applications are feasible, broad spectrum of treatment trains applied to make water fit for different purposes
- Wastewater reuse, in particular for agriculture, is of increasing importance to cope with water scarcity. Reused water can constitute an important alternative water resource and avoid polluted discharge.
- Disinfection is mandatory (for potentially high contact use): Chlorination is predominant, UV is becoming more important.
- Industrial recycling and reuse is embedded in cleaner production methods. End of pipe technologies often involve dense membrane processes or other advanced technologies for safe retention of key contaminants.
- Implementation can be challenging and encompasses political, institutional, social, technical, organizational, legal and economic requirements

Feasiblity Studies & Documentation





http://www.aquarec.org



Excel Tool & Article are Open Access:
https://www.mdpi.com/2073-4441/11/1/153

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Thanks for your interest

Questions?